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Full Length Article

The use of mint and thyme extracts as eco–friendly natural dyes and the antimicrobial properties of dyed products

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ABSTRACT

In this study, the dyestuff and antimicrobial properties were examined using extracts obtained from mint (*Mentha spicata* L.) and thyme (*Thymus vulgaris* L.) plants. Cotton and woolen fabric samples were used in the dyeing process using pre–, meta–, post– mordant, and non–mordant dyeing methods. $CuSO_4$, $FeSO_4$, and $AlK(SO_4)_2$ mordants were used as stabilizers and color changers. The color analysis of the dyed textile samples was evaluated in terms of rubbing, washing, and light fastness values. The color codes were determined with the Pantone Color Guide, and the L^*, a^*, b^*, C^*, h^o, and K/S values were detected with a color measurement spectrophotometer. The highest K/S value was measured as 23.050 for $FeSO_4$ with meta–mordanting method for dyed wool yarn using thyme extract. The antimicrobial properties of the dyed fabrics were determined by the disk diffusion method. Among the mordants used, dyeing with $CuSO_4$ showed better antimicrobial properties than other mordants. As the textile dyed products possess antimicrobial properties, we believe their use in health centers will make a positive contribution to hygiene. As a result, it was determined that extracts obtained from mint (*Mentha spicata* L.) and thyme (*Thymus vulgaris* L.) plants were effective natural dye sources for textile products.

1. Introduction

Dyes and pigments are colorants that are widely used especially in dyeing textiles, food, and many other important materials (Yadav et al., 2023; Wang et al., 2022). The dyes used today are either prepared naturally or synthetically. Natural dyeing is prepared from parts of plants such as stems, roots, flowers, leaves, fruits, and barks and is widely used in dyeing textiles or similar materials (Che and Yang, 2022). Synthetic dyes are chemically synthesized products that are low-cost, durable, have a wide color range, and are easy to apply (Hagan and Poulin, 2021; Pizzicato et al., 2023). In addition to the advantages of synthetic dyes, many of the auxiliary substances and dyeing wastes pose a serious threat to the environment and human health (Pizzicato et al., 2023). In order to minimize the damages caused by chemicals, natural mordants known as environmentally friendly biomordants have come to the fore in recent years (Çolak et al., 2021). Satisfactory dyeing and durability properties of biomordants make them stand out as an important alternative (Hosseinnezhad et al., 2023). Therefore, the search for environmentally friendly dyestuffs in the textile industry continues rapidly. In addition, most natural dyes have also been reported to have biological activities such as antimicrobial, anti-inflammatory, antioxidant, anti-cancer and antiviral properties (Li et al., 2022; Di Salvo et al., 2023). However, limited availability and high costs have made the industrialization of natural dyes difficult (Hou et al., 2013).

Mint (*Mentha spicata* L.), a member of the Lamiaceace family, is a perennial herb and is cultivated mainly in the countries like USA, India, China, and Iran (Kushwaha et al., 2024). Thyme (*Thymus vulgaris* L.), another plant belonging to the Lamiaceae family, is grown especially in the Mediterranean region and Europe (Shin and Ko, 2024). Mint and thyme are spices commonly used in food and beverage products due to their flavor, aromatic, and medicinal qualities (Soleimani et al., 2022). As medicinal plants, they also have various biological properties including expectorant, antirheumatic, anti-allergic, antiseptic, antioxidant, and antimicrobial activity (Fadli et al., 2014; Nwozo et al., 2023; Anantharaman et al., 2014). At the same time, the usability of these plants as dyestuffs has been proven in various studies in the literature (Tutak et al., 2014; Arık et al., 2020).

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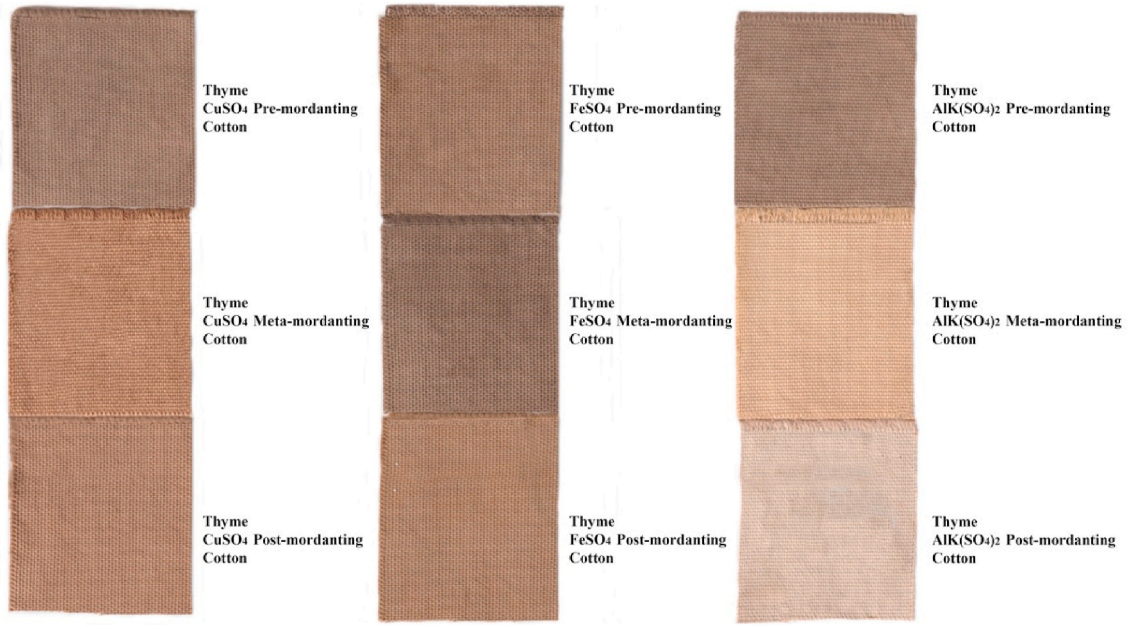

Fig. 1. Cotton fabrics dyed using thyme extracts.

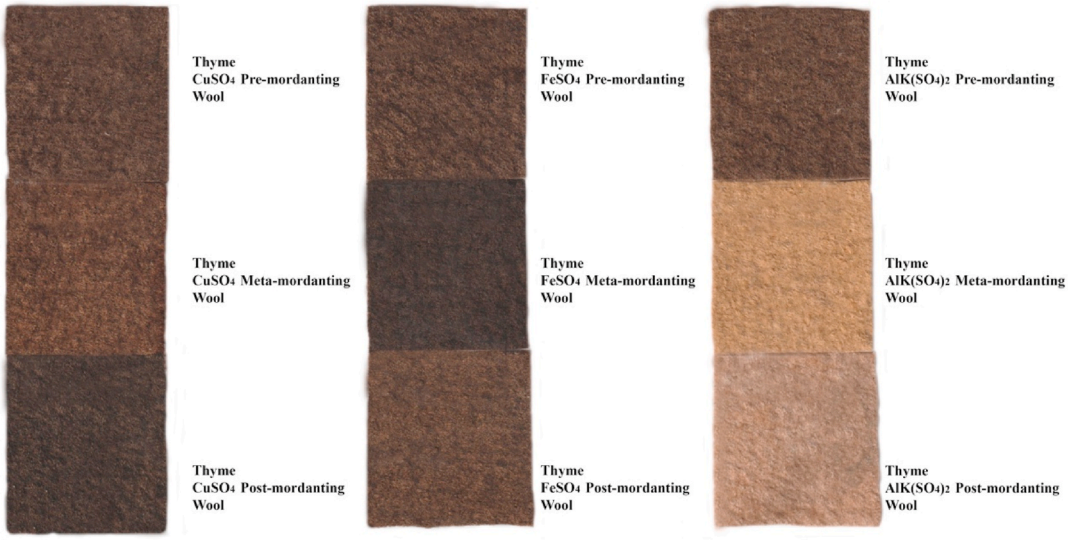

Fig. 2. Wool fabrics dyed using thyme extracts.

With the developing technology, ultrasonic, gamma, ultraviolet, plasma, and microwave radiation are used as modern extraction methods. These methods have very important advantages. However, in the current study, the extraction process was carried out using the Soxhlet method, which is a low–cost traditional method (Zia et al., 2019; Adeel et al., 2022). In this study, the dyeing properties and antimicrobial activities of woolen and cotton fabrics dyed with mint (*Mentha spicata* L.) and thyme (*Thymus vulgaris* L.) leaf extracts were investigated. For this purpose, cotton and woolen fabric samples were dyed with $CuSO_4.5H_2O$, $FeSO_4.7H_2O$ and $AlK(SO_4)_2.12H_2O$ mordants using dyestuff obtained from mint and thyme leaves. Then, the antimicrobial activities of the fabrics were evaluated.

2. Materials and methods

A mordant is the binding or stabilizing auxiliary substances used in the dyeing process. Mordants bind the dye to the fiber and enable the formation of new color tones. In this study, the mordants used were prepared as in previous studies (Önal et al., 2020, 2021, 2022). Mint and thyme were collected in May from the Tokat, Türkiye. All mordants ($CuSO_4.5H_2O$, $FeSO_4.7H_2O$ and $AlK(SO_4)_2.12H_2O$) were purchased from Merck. The cotton and wool yarn (278 g/m^2 – 394 g/m^2, respectively) were obtained from Toga Textile Ltd., Tokat, Türkiye.

2.1. Pre–mordanting method

The samples were boiled with 100 mL of 0.1 M mordant solution for 20 min and filtered. The sample was boiled in an Erlenenmeyer flask with the dyestuff at 75 °C for wool fabric and 90 °C for cotton fabric for 1 h. They were then cooled, filtered, rinsed, and dried.

2.2. Meta–mordanting method

The samples are placed in 100 mL of dye solution. A gram of solid

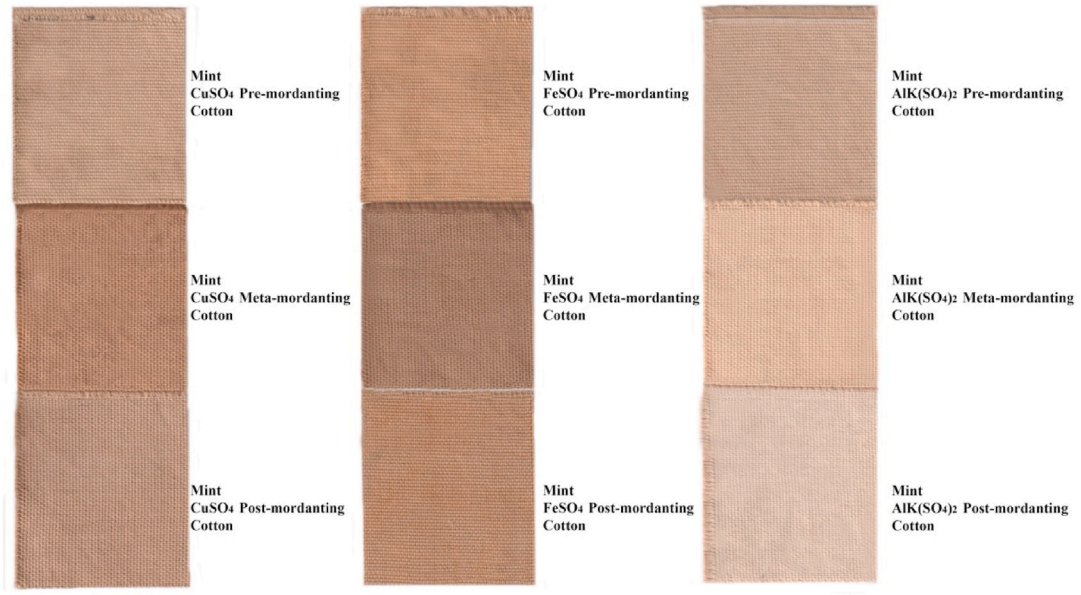

Fig. 3. Cotton fabrics dyed using mint extracts.

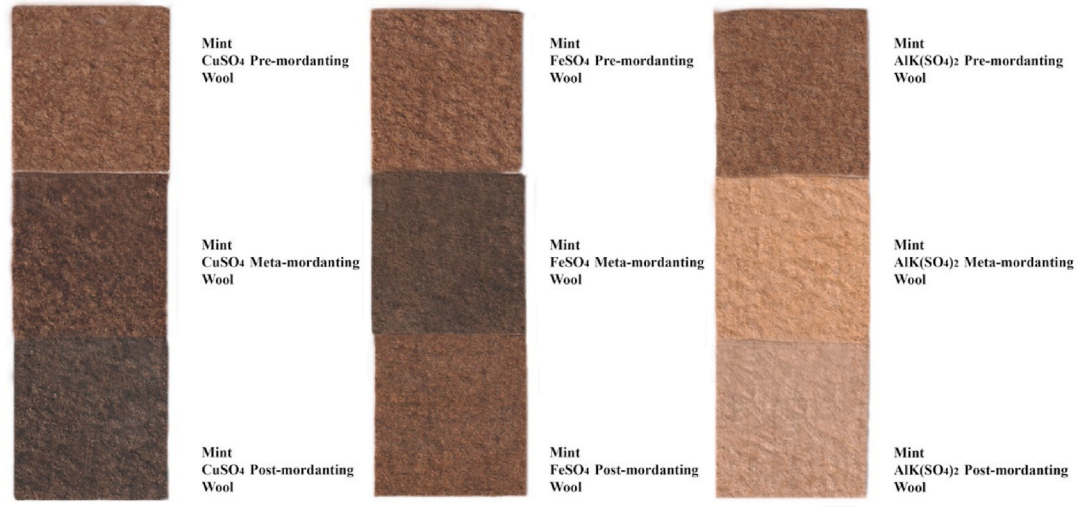

Fig. 4. Wool fabrics dyed using mint extracts.

mordant equivalent to the amount of 0.1 M in 100 mL of the substance was added and boiled for 1 h at 75 °C for woolen fabric and 90 °C for cotton fabric, cooled, filtered, rinsed, and dried.

2.3. Post–mordanting method

In this method, the samples were boiled in an Erlenenmeyer flask with the dyestuff at 75 °C for wool fabric and 90 °C for cotton fabric for 1 h, then filtered. They were subsequently boiled with 100 mL of 0.1 M mordant solution containing iron sulfate, copper sulfate, and alum for 20 min. The samples were then cooled, filtered, rinsed, and dried.

2.4. Without–mordanting method

The samples were boiled in an Erlenenmeyer flask with dyestuff at 75 °C for woolen fabric and 90 °C for cotton fabric for 1 h, cooled, filtered, rinsed and dried.

2.5. Washing of dyed samples

In accordance with ISO standards, the dyed samples were washed in a 1/50 flotte ratio and 5 g/L soap solution at 40 °C for approximately 30 min. It was first rinsed twice with distilled water, then rinsed with tap water for 10 min and dried. Grey scale was used to determine color change in the uncovered portion of the sample.

2.6. L^*, a^*, b^*, C^*, h^o and K/S values

The color properties of the dyed samples were evaluated by Premier Colorscan SS 6200A spectrophotometer in terms of CIELab values (L^*, a^*, b^*, C^*, h^o) and color strength (K/S) values. L^* indicates the lightness and darkness of the dyed fabric. As the L^* value approaches 0, darkness increases, and as it approaches 100, lightness increases. The a^* and b^* values gave positive results in all dyed fabrics. Positive a^* values indicate that colors shift towards red, and positive b^* values indicate that colors shift towards yellow. The a^* and b^* values of woolen fabrics dyed with thyme extract gave positive results. Positive a^* values indicate that

Fig. 5. Cotton and wool fabrics dyed without mordant using thyme and mint extracts.

colors shift towards red, and positive b^* values indicate that colors shift towards yellow. In cotton fabrics dyed using mint and thyme extracts and alum, the a^* value gave negative (−) results in the meta– and post–mordanting methods and the colors shifted towards green. The b^* value is positive (+) in all dyeing methods and the colors shift to yellow. The rotation angle "h" (in degrees), which increases from red to yellow, is a measure of color. A dot away from the neutral point represents chroma (C^*), which is a measure of the vividness of a color at a given brightness (L^* value) (Benli, 2017).

The spectral reflectance measurements of the naturally dyed fabrics were determined using a Konica Minolta 3600d spectrophotometer (Japan). Color strength was expressed as K/S values of the dyed samples using the Kubelka–Munk equation (Malčić et al., 2011):

$$K / S = (1 - R)^2 / 2R$$

where K is the absorption coefficient, R is the reflectance of the dyed sample and S is the scattering coefficient.

2.7. Antimicrobial tests

In this study, *Bacillus subtilis* ATCC 6633, *Pseudomonas deruginosa* ATCC 9027, *Salmonella enteritidis* ATCC 13076, *Streptococcus pyogenes* ATCC 176, *Candida albicans* ATCC 10231, and *Acinetobacter baumannii* were used. Erythromycin, cefoperazone-sulbactam, and voriconazole were used as antibiotics. Additionally, nutrient broth (NB), a commonly used medium for bacteria, was used. The dehydrated medium was dissolved in distilled water to 20 g/L and autoclaved at 121 °C for 15 min. When the temperature of the media reached 45–50 °C, 20 mL was poured into petri dishes. The pH of the medium was 7 ± 0.2 at 25 °C.

Antimicrobial activity tests were performed according to the disk diffusion method. 20 µL of the previously prepared bacterial suspension at 0.5 McF concentration was transferred to the fabric samples. These samples were then transferred to tubes containing 4 mL NB. The prepared samples were incubated at 36.5–37 °C for 24h. After incubation, turbidity was observed in the tubes and the results were recorded.

The fabric samples were left in petri dishes. Air contamination of petri dishes was ensured for 25 days. The samples kept open in the Petri dishes were closed and taken into the sterile cabinet. Samples in petri dishes were transferred to tubes containing 4 mL NB. The tubes were incubated at 36.5–37 °C for 24 h. After incubation, the results were reported considering the turbidity of the tubes.

3. Results and discussion

3.1. Dye properties of mint and thyme extracts

This study investigated the use of natural textile dyes prepared with mint and thyme extracts, both with and without mordants. Wool and cotton fabrics dyed with and without mordant using thyme and mint extracts are provided in Figs. 1–5.

The light fastness (Atlas weather–ometer), wash fastness (Launder–ometer), and crock fastness (255 model crock–meter) of all dyed samples were determined according to ISO 105–C06 and CIS. The light, washing, and rubbing fastness values of fabrics dyed with $CuSO_4$, $FeSO_4$,

Table 1
Rubbing fastness values of woolen and cotton fabrics dyed with mint and thyme extracts.

			Dry			Wet		
			$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$	$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$
Mint extract	**Pre–mordanting**	**Wool**	5	5	5	5	4	5
		Cotton	5	4–5	5	4	2	2–3
	Meta–mordanting	**Wool**	4	4	5	2–3	3	5
		Cotton	5	4	5	3–4	2–3	5
	Post–mordanting	**Wool**	5	3	5	3	1–2	5
		Cotton	5	4	5	3–4	1–2	5
	Without mordanting	**Wool**	5			4–5		
		Cotton	5			5		
Thyme extract	**Pre–mordanting**	**Wool**	5	5	4–5	4	3–4	3–4
		Cotton	5	4–5	5	2	2–3	2–3
	Meta–mordanting	**Wool**	4	3	5	4	2–3	3–4
		Cotton	4–5	4	5	3	4	4
	Post–mordanting	**Wool**	5	4	5	5	2–3	5
		Cotton	5	3–4	5	4	1	4
	Without mordanting	**Wool**	5			4–5		
		Cotton	5			4–5		

1 = poor, 2 = moderate, 3 = fairly good, 4 = good, 5 = very good.

Table 2
Washing fastness values of woolen and cotton fabrics dyed with mint and thyme extracts.

		Mint extract			Thyme extract		
		$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$	$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$
Pre–mordanting	**Wool**	2–3	3–4	4–5	2–3	3	2
	Cotton	3–4	2–3	3	2	2–3	2–3
Meta–mordanting	**Wool**	3–4	4–5	4	4	2	5
	Cotton	4	4	3	3	4	4
Post–mordanting	**Wool**	3	1–2	4–5	5	3–4	4
	Cotton	4	3–4	5	4–5	3	3–4
Without mordanting	**Wool**	4			3		
	Cotton	4–5			4–5		

1 = poor, 2 = moderate, 3 = fairly good, 4 = good, 5 = very good.

Table 3
Light fastness values of woolen and cotton fabrics dyed with thyme and mint extracts.

		Mint extract			Thyme extract		
		$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$	$CuSO_4$	$FeSO_4$	$AlK(SO_4)_2$
Pre–mordanting	**Wool**	6	6	7–8	6	7	6–7
	Cotton	7	7	7	7	7	7
Meta–mordanting	**Wool**	6	7	6–7	7	7	6
	Cotton	7	7	7	7	7	6
Post–mordanting	**Wool**	7	6–7	7	6	7	7
	Cotton	7	6–7	6	7	7–8	7
Without mordanting	**Wool**	7			6–7		
	Cotton	6			6–7		

1 = poor, 2 = moderate, 3 = fairly good, 4 = good, 5 = very good, >6 = excellent.

Table 4
Color codes of woolen and cotton fabrics dyed with thyme and mint extracts according to the dyeing method and conditions.

	Dyeing Method	Mordant	Wool				Cotton			
			Heat (°C)	Time (min.)	Color	Color Code	Heat (°C)	Time (min.)	Color	Color Code
Mint	**Pre– mordanting**	**$CuSO_4$**	75	60	Dullgreen	18–0840	90	60	Silver fern	15–0719
		$FeSO_4$	75	60	Cornstalk	16–1815	90	60	Dryedmass	14–0626
		$AlK(SO_4)_2$	75	60	Drab	18–0939	90	60	Greenhazel	14–0615
	Meta– mordanting	**$CuSO_4$**	75	60	Oliverdrab	18–0622	90	60	Swarmp	15–6310
		$FeSO_4$	75	60	Dullgreen	18–0840	90	60	Lylacgrey	17–3906
		$AlK(SO_4)_2$	75	60	Cream	17–6714	90	60	Chardonnay	13–0633
	Post– mordanting	**$CuSO_4$**	75	60	Purplesage	18–3712	90	60	Arabgrey	15–1119
		$FeSO_4$	75	60	Ambergreen	17–0840	90	60	Greygreen	16–0518
		$AlK(SO_4)_2$	75	60	Sharpfern	15–0719	90	60	Alabaster	12–0812
Thyme	**Pre– mordanting**	**$CuSO_4$**	75	60	Oliverdrab	18–0622	90	60	Naturel grey	17–4402
		$FeSO_4$	75	60	Nutria	18–0825	90	60	Greygreen	16–0518
		$AlK(SO_4)_2$	75	60	Coffee	19–0812	90	60	Cloudgrey	15–3802
	Meta– mordanting	**$CuSO_4$**	75	60	Drab	18–0839	90	60	Amberlight	14–1217
		$FeSO_4$	75	60	Purpleash	17–3810	90	60	Purpleash	17–3810
		$AlK(SO_4)_2$	75	60	Beechorset	14–0428	90	60	Light sulphur	11–0620
	Post– mordanting	**$CuSO_4$**	75	60	Amber brown	17–1142	90	60	Kelp	17–1022
		$FeSO_4$	75	60	Tan	16–1334	90	60	Taffy	16–0940
		$AlK(SO_4)_2$	75	60	Elmwood	17–1029	90	60	Beg	14–1118

and $AlK(SO_4)_2$ mordant and dyestuffs obtained from mint and thyme by pre–, meta–, post–mordanting and mordant–free dyeing methods are given in Tables 1–3.

In woolen fabric dyeing using the pre–mordanting method with mint extract, dry and wet rubbing fastness values showed the best results in all mordant types except the wet rubbing test with $FeSO_4$ (Table 1). Dry rubbing fastness values showed the best results (4–5) in cotton sample dyeing using the pre-mordanting method with mint extract. Wet rubbing fastness values received lower scores (3–4) than dry rubbing fastness values. It can be said that this is due to the partial dissolution of the dyestuff in water during wet rubbing. Dry and wet rubbing fastness values showed the best results (5) in wool fabric dyeing with $AlK(SO_4)_2$ mordant using the mordanting method with mint extract. Dry and wet rubbing fastness values showed the best results (4–5) in the dyeing of woolen fabrics using the pre–mordanting method with thyme extract. In samples dyed with both mint and thyme, wet rubbing fastness values received lower scores (3–4) than dry rubbing fastness values. The dry rubbing fastness value gave the best result (5) in wool fabric dyeing with $AlK(SO_4)_2$ mordant using the mordanting method with thyme extract. It is thought that the reason why some mordants have low wet rubbing fastness values is due to the dissolution of mordants in water.

The washing fastness of wool and cotton samples dyed with mint and thyme extracts are given in Table 2. The best washing fastness was obtained with mint extracts was found by using $AlK(SO_4)_2$ in the post-mordanting method, while with thyme extracts it was obtained by using $CuSO_4$ in the post-mordanting method.

The light fastness of wool and cotton samples dyed with and without mordant using mint and thyme extracts are given in Table 3. The best value was obtained in the dyeing of wool samples in the pre–mordanting method using $AlK(SO_4)_2$ with mint extracts. The best value was obtained

Table 5
L^*, a^*, b^*, C^*, h^o and K/S values of wool and cotton fabrics dyed with thyme and mint extracts.

			Wool						Cotton					
Mint	**Dyeing Method**	**Mordant**	***L****	***a****	***b****	***C****	***h*°**	***K/S***	***L****	***a****	***b****	***C****	***h*°**	***K/S***
	Pre– mordanting	**$CuSO_4$**	38.5492	3.8003	21.3802	21.7153	79.9211	14.122	64.1313	1.6003	25.8429	25.8924	86.4566	3.025
		$FeSO_4$	37.7421	4.3778	22.0033	22.4346	78.7474	15.249	63.6102	4.0360	31.3500	31.6088	82.6641	3.972
		$AlK(SO_4)_2$	39.6017	3.5062	21.9894	22.2672	80.9404	13.636	66.6816	1.0724	25.0083	25.0313	87.5445	2.468
	Meta– mordanting	**$CuSO_4$**	24.8333	2.6412	10.7634	11.0827	76.2128	22.052	53.6658	4.8258	24.8143	25.2791	78.9947	5.176
		$FeSO_4$	31.4953	0.3264	15.5469	15.5503	88.7974	18.243	54.4448	3.0189	23.2517	23.4158	82.6024	4.613
		$AlK(SO_4)_2$	61.9814	31.1289	37.9767	38.1053	85.2901	7.335	76.2484	−0.0895	30.3827	30.3828	90.1689	1.898
	Post– mordanting	**$CuSO_4$**	25.7284	0.5079	9.7411	9.7543	87.0152	19.673	58.6886	3.0811	23.6718	23.8715	82.5841	3.592
		$FeSO_4$	33.9779	3.2287	19.3700	19.6373	80.5368	17.763	58.0067	4.4903	28.5900	28.9405	81.9405	4.784
		$AlK(SO_4)_2$	61.2297	3.0769	31.1922	31.3435	84.3663	4.973	81.1317	−0.8750	23.5380	23.5543	92.1290	0.894
	Without mordanting	–	61.5898	2.6415	31.5964	31.7066	85.2210	5.065	77.8993	0.1249	25.7959	25.7962	89.7226	1.252
Thyme	**Pre– mordanting**	**$CuSO_4$**	29.5130	2.1566	14.5742	14.7329	81.5830	20.020	51.2945	1.5535	19.7884	19.8492	85.5113	5.482
		$FeSO_4$	30.2546	1.6761	14.7008	14.7960	83.4955	18.775	52.5099	2.6078	23.2028	23.3489	83.5873	5.990
		$AlK(SO_4)_2$	31.0388	2.3764	17.2668	17.4295	82.1636	21.233	54.6487	1.3474	20.7077	20.7515	26.2773	4.662
	Meta– mordanting	**$CuSO_4$**	30.3748	3.7509	16.3877	16.2115	77.1079	19.588	56.5414	5.3644	28.7597	19.8552	85.4493	5.739
		$FeSO_4$	24.5862	0.6171	10.3211	10.3395	86.5783	23.050	47.7691	1.6254	19.7490	19.8157	85.2951	6.620
		$AlK(SO_4)_2$	59.8003	2.4307	40.3348	40.4379	86.5514	9.822	74.1351	−0.4852	35.9324	35.9356	90.7736	3.292
	Post– mordanting	**$CuSO_4$**	25.5876	1.0624	11.4364	11.4856	84.6929	22.052	58.0094	4.2959	26.0379	26.3999	80.6313	4.332
		$FeSO_4$	33.4359	2.6134	18.2621	18.4482	84.8559	17.064	56.3404	3.7521	26.9305	27.1906	82.0683	5.015
		$AlK(SO_4)_2$	59.5248	2.6304	29.4043	29.5217	84.8882	5.101	78.5080	−0.5463	24.4281	24.4342	91.2811	1.144
	Without mordanting	–	58.7753	3.6968	29.9855	30.2125	82.9717	5.449	75.9911	0.6591	24.2004	24.2094	88.4399	1.351

Table 6
Antimicrobial test results of dyed samples (mm).

Extract	Mordant	Materials	Microorganisms					
			Bacillus subtilis	*Pseudomonas deruginosa*	*Salmonella enteritidis*	*Streptococcu spyogenes*	*Acinetobacter baumannii*	*Candida albicans*
Mint	**Meta– $CuSO_4$**	**Wool**	15	–	12	15	12	–
Mint	**Meta– $CuSO_4$**	**Cotton**	11	14	13	19	17	8
Thyme	**Post– $CuSO_4$**	**Cotton**	5	16	15	16	15	8
Mint	**Post– $CuSO_4$**	**Wool**	11	20	19	21	–	20
Thyme	**Post– $CuSO_4$**	**Wool**	–	–	25	17	–	15
Antibiotics								
Erythromycin			20	16.5	10.5	16.5	13.5	18
Cefoperazone-sulbactam			20	18	15	19.5	15	22.5
Voriconazole			19	19	21	28	27	19.5

Fig. 6. Antimicrobial turbidity tests.

in the dyeing of cotton samples in the post mordanting method using thyme extracts and $FeSO_4$. In addition, the dyeing conditions of wool and cotton fabrics dyed with mint and thyme extracts and their color codes according to Pantone Color Guide are given in Table 4. According to Table 4, when the boiling degrees of the samples are increased, the changes in color tones are remarkable.

In wool and cotton fabrics dyed with mint extract, the highest *K/S* values were obtained by the meta–mordanting method with $CuSO_4$ mordant, while the lowest *K/S* values were obtained from the post mordanting method with $AlK(SO_4)_2$ mordant (Table 5). In wool fabrics dyed with thyme extract, the highest *K/S* values were obtained by the meta–mordanting method with $FeSO_4$ mordant, while the lowest *K/S*

values were obtained from the post mordanting method with $AlK(SO_4)_2$ mordant (Table 5).

3.2. Antimicrobial tests

Antimicrobial test results (mm) of the dyed samples are given in Table 6. Wool samples dyed according to the meta–mordanting method using mint extract together with $CuSO_4$ mordant gave positive results against *Bacillus subtilis*, *Salmonella enteritidis*, *Streptococcus pyogenes*, and *Acinetobacter baumannii* microorganisms in the evaluation made by disk diffusion method. Cotton samples dyed according to the meta–mordanting method with $CuSO_4$ mordant using thyme extract and wool samples dyed according to the post–mordanting method with $CuSO_4$ mordant using mint extract gave positive results against all microorganisms. Wool samples dyed according to the post–mordanting method with $CuSO_4$ mordant using thyme extract gave the best results against *Salmonella enteritidis*, *Streptococcus pyogenes*, and *Candida albicans* microorganisms. No positive results were obtained on cotton and woolen fabrics tested as control samples. In Table 6, six different dyed fabrics that exhibited the best antimicrobial activity (>19 mm) were impregnated with bacteria according to the disc diffusion method. Samples were placed in test tubes and incubated for 24 h. As seen in Fig. 6, no turbidity was observed in the tubes. This result shows that there is no bacterial growth in the fabric samples.

4. Conclusion

In the study, extracts were prepared from dried and ground mint and thyme plants. A total of forty woolen and cotton fabrics were dyed with $FeSO_4$, $CuSO_4$, and $AlK(SO_4)_2$ mordants using pre–, meta– and post–mordanting, and non–mordanting dyeing methods. The rubbing, washing, and light fastness values of the dyed samples were investigated. Then, the antimicrobial activities of the dyed fabrics were tested. As the antimicrobial activity results of dyeing with $CuSO_4$ mordant are positive, the fabrics dyed with this method can be used in the healthcare sector. In addition, the good level of light, washing, and rubbing fastness of the dyed samples shows that thyme and mint extracts can be a suitable dye source for dyeing textile products in natural dyeing. When the color quality and fabric adhesion properties of the prepared natural dyes are evaluated, it is observed that they will be an important alternative to synthetic dyes. Natural dyes prepared with mint and thyme extracts are environmentally friendly and have an important place in the dyeing of textile products.

CRediT authorship contribution statement

Sercan Gümüştekin: Investigation, Formal analysis. **Adem Önal:** Supervision, Investigation, Formal analysis. **Oğuz Özbek:** Writing – original draft, Investigation, Formal analysis. **İsa Karaman:** Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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